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The Impacts and Implications of Anthropogenic Forces on the Unstable Geologic Platform in Parts of Anambra and Imo States Southeastern, Nigeria

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Abstract: Anthropogenic activities have exacerbated the incidences of floods, soil and gully erosion and landslides in parts of southeastern states of Anambra and Imo, Nigeria. Intense urbanization, deforestation, agricultural, commercial/industrial activities has extensively-denudated and elluviated the total environment. The variations in climatic condition also have associated implications. The rainy season registers an average annual rainfall of 2000 mm. The Geology comprises an unstable platform of a regional escarpment/cuesta subtended by sandy, highly-fractured and faulted Nanka sands/Ameki Formation. The underlying unstable geology facilitates the development of gullies with depth ranging from 2 m to over 80 m. The calculated rate of soil removal from the gully prone areas is about 9.20 to 10.16 ton/ha/yr. The significant cuesta of the area with steep scarp slope and gentle dip slope forms both surface and groundwater divide that also facilitates gully and landslide developments. The underlying geologic sandy structure is quite porous and permeable with huge aquiferous horizons of high pore-water pressures and effective stress. The problems of laissez faire attitude and poor understanding of the destructive implications of the unstable regional geologic platform result in the failure of measures to prevent myriads of environmental destructions and economic wastes.

Keywords: Geology, Unstable Platform, Anthropogenic Activities, Gully Erosion, Landslides, Environmental Degradation

1. Introduction

Geological Sciences or Earth Sciences or Applied Geology is keyed towards fully-understanding the constituents and geotechnical intricacies of the earthly environment and being able to use the realized knowledge to control any arising problems and implications in anthropogenic activities. The geologic formations of the study area are the underlying clayey/shaley Imo Shale overlain by the Nanka Sands in Anambra State and the Imo State geologic equivalent of sandy Ameki Formation. Parts of southeastern, Nigeria (Fig. 1) has been severely-gullied resulting to colossal losses in human lives and property. The gullies mostly developed where the contributing effects of land use, climate and slope interact [1] These disasters are exacerbated by myriads of anthropogenic activities. The gully heads/fronts emanate and are associated with the N-S trending Agulu-Nanka-Ekwulobia-Orlu escarpment in the region. The escarpment consists of the steep east scarp slope and the gentle west dip slope. The gully problems are more on the scarp slope than on the dip slope. Gully sites at Agulu, Adazi Ani, Nanka, Oko, Ekwulobia, Uga, Umuchu etc are along the scarp slope while the dip slope hosts the gully sites of Adazi, Alor, Oraukwu, Nnobi, Abatete and Ideani. Major rivers such as Mamu, Uchu, Idemili, Odo and Orashi emanate from both the scarp and dip slopes of the escarpment. The rivers form eroding agents wreaking havoc on the unconsolidated geologic unit of the area.

Development of old communities into urban/semi-urban centres with social amenities of power supply, water and population growth due to increased socioeconomic activities all impact on the land exposing the ground surface to

gullying especially on the scarp slope of the Awka-Orlu escarpment. These slopes are underlain by young sedimentary materials and sandstone boulders that support and carry the load. These are geotechnically formed and inherent in them, are fractures, joints, faults, folds and grabens. The pore spaces can be syn-depositional or post depositional with resultant high porosity and permeability. The interconnectivity of the pore spaces also plays major role in groundwater movement and gully erosion development. The hydrodynamic properties of water in huge aquifers also cause more problems. The effluents end up in the rivers, lakes, dry valleys and marsh lands. Added to these geotechnical problems is the overhead pressure due to continued vertical and horizontal loading from deforestation and urbanization by anthropogenic agencies. The high average rainfall amount of about 2000 mm has its own surficial impact and some of the water infiltrate directly. These problems are not appreciated by government that infrastructure such as roads are constructed without drainages thereby facilitating gully development and growth. Anthropogenic activity such as agriculture also induces gully erosion with resultant soil loss and surface water siltation [2, 3]. This study is aimed at evaluating the consequences of anthropogenic activities on the unstable geologic environment of southeast, Nigeria. Appropriate land management techniques are important in the study area where the geotectonic, geologic, and geohydrologic characteristics of the region make many areas within it susceptible to gully erosion [4]. Areas prone to gully and landslide should be delineated and anthropogenic activities that trigger and facilitate gully/landslide development avoided in such areas.

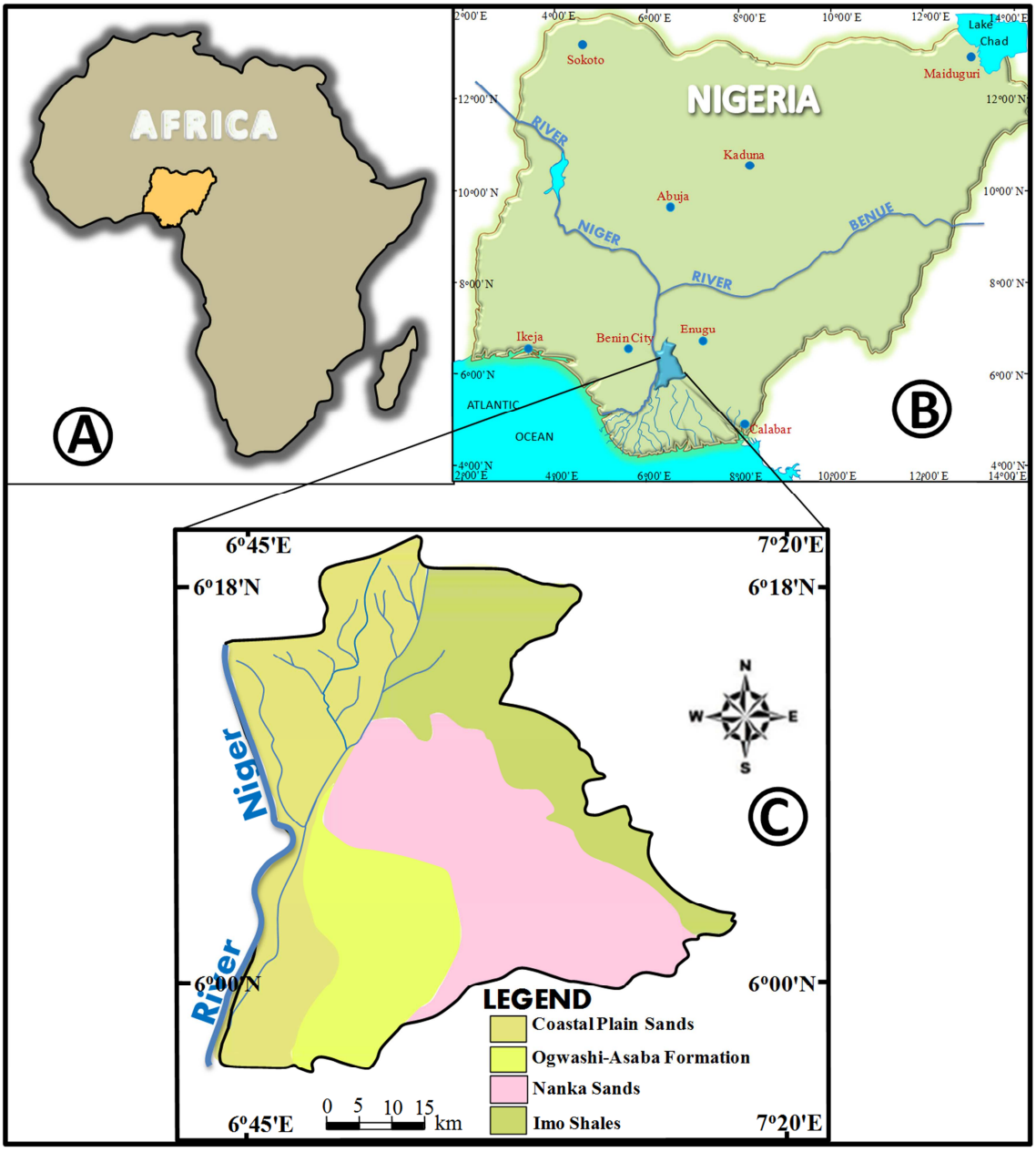

Fig. 1. *Location map of the study area.*

2. Geotechnical Problems and Implications of Anthropogenic Forces

Anthropogenic activities have greatly exacerbated the soil and gully erosion incidences and landslides in the study area. It is hereby-predicted and feared that in the not-a-much-distant future, major landslides may occur in some of the present heavily-built-up and highly-populated urban and sub-urban communities, now, perching at the apices and slopes of some of the highly-faulted and fractured cuestas/escarpments in the areas. Such cuestas include the Agulu-Nanka-Oko-Ekwulobia, Alor-Oraukwu-Adazi, Osina-Orlu etc. Many of the built-up hills in the study area are situated on the scarp or dip slopes of these escarpments. Anthropogenic activities and urbanization events have not considered the implications of these geotechnical weaknesses and aquiferous horizons in their planning and design of the consequent infrastructure. The fear is that if major landslides were to occur in these endangered platforms, there would be calamitous loss of lives and property. Specific towns like Agulu, Nanka, Oko, Ekwulobia, Adazi, Alor, Oraukwu, Okwudor, Okigwe, Orlu are severely affected by the geotechnical characteristics of the environmental platforms. The oil/gas prospecting and production activities in parts of the Niger Delta; the consequent and extensive vehicular movements; the widespread atmospheric pollution and water contamination from acid rains equally endanger southeastern environments. They contribute to the total breakdown of infrastructures such as roads, water schemes, houses, monuments etc. There are fractures (joints and faults) on the slopes of the escarpment/cuesta on which buildings are erected. With increase in urbanization the total pressures will be mounted on the fractures causing more instability, slope failures and landslides.

3. Materials and Methods of Study

The study involved field geologic mapping, laboratory work and identification of gully and landslide sites in the study area. At each gully site, coordinates and elevation were measured using Garmin GPS. Samples for geotechnical analysis were collected from the gully base because of the instability of the gully walls. The dimensions of the gullies were measured only at accessible sites using tape and calibrated rope. The present Digital Elevation Model of the area was produced using ArcGis software.

4. Result and Discussion

The depth to gully in accessible areas ranges from 2.5m to 90 m fig. 2. More number of gullies in active stage of development was observed in the area with depth increasing with season. The concentration of the gully erosion and landslide in the area varies from areas of high hydraulic head to areas of low hydraulic head [5]. Conscious efforts were also made in relation to the effects of climate change in recent times *vis-à-vis* these extensive ecological disasters that are ravaging the study area, namely, the high temperatures, the excessive aridity during the dry season, the high temperature impacts on the exposed pedologic and geologic features that have been denuded through deforestation.

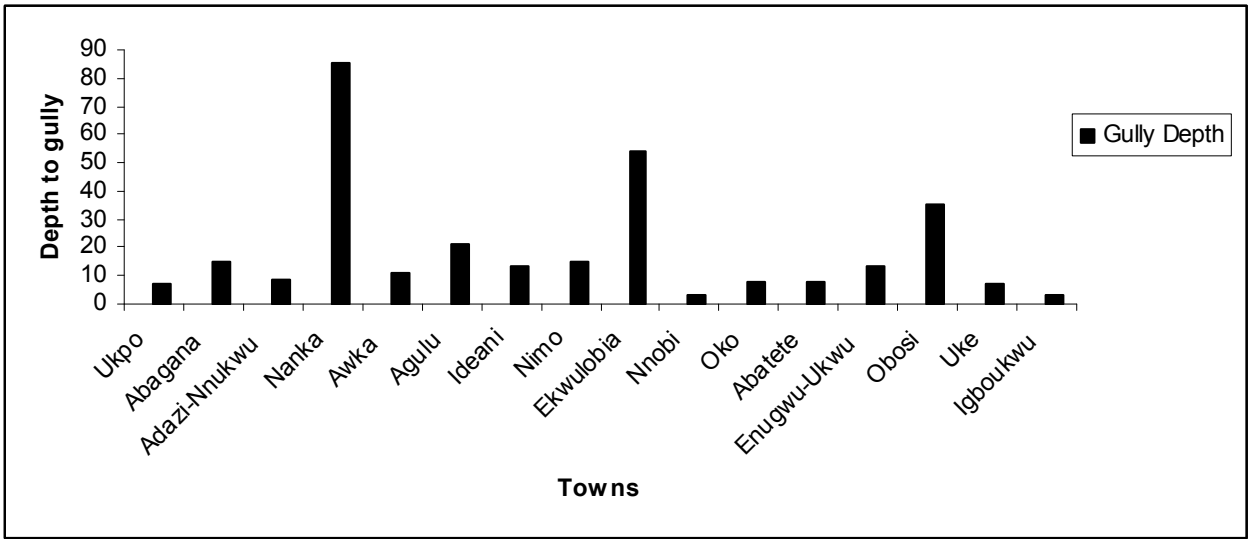

Fig. 2. *Depth of accessible gully sites in the area.*

Natural and anthropogenic factors work in tandem to initiate and facilitate gully and landslide development and growth [6]. The high rainfall intensity and amount of about 2000 mm play major role in the removal or loss of soil sediments facilitating erosion. The rate of soil loss in the area range from 9.20 to 10.16 ton/ha/yr [7]. The eroded loose soil end up in the lakes, streams and rivers resulting in the siltation and pollution of these surface water bodies while the elevation of the area is gradually lowered. The DEM reflecting the current elevation of the area is as produced using GIS software (Fig. 3 a & b).

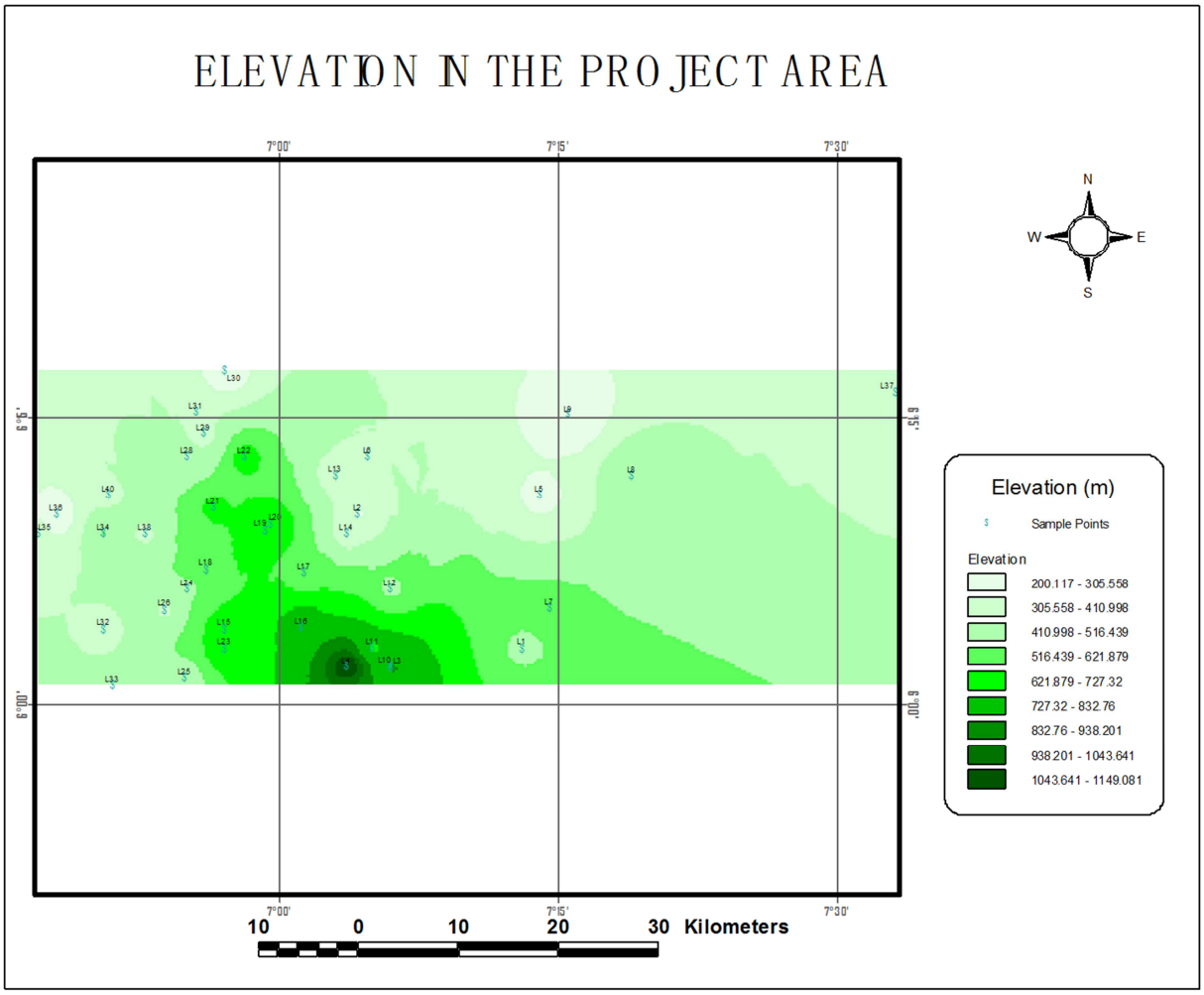

Fig. 3a. *Current elevation map of the study area.*

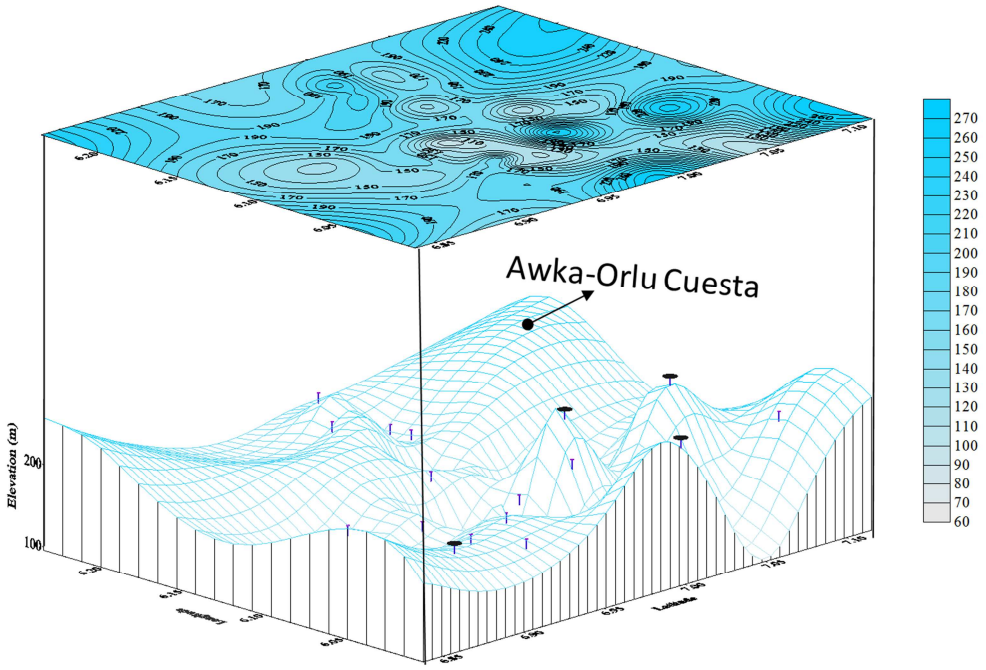

Fig. 3b. *Digital Elevation Model of the study area showing the escarpment.*

4.1. Implications of Geology on Gully Erosion and Landslide Problems

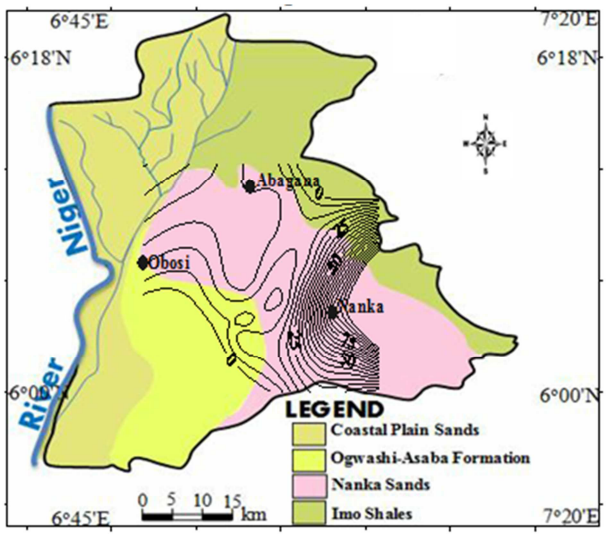

Fig. 4. Geologic map of the study area with concentration of gully on Nanka Sands.

The study area is mainly-located in the Anambra Basin, Nigeria and is characterized by the Santonian uplift [7]. Earlier authors such as [8 -10] gave a detailed account of the Geology of Anambra Basin. Recent contribution by [5] and [12] also highlighted the various geologic formations prevalent in the basin. The study area is predominantly covered by lose, friable unconsolidated Nanka Sands (Eocene) and underlain by impermeable Imo Shale (Palaeocene). The Nanka Sands constitutes the Agulu-Nanka-Ekwulobia-Orlu escarpment significant in the hydrogeological and geohazards studies of the area. The unconsolidated, loose, friable and uncemented properties of Nanka Formation facilitate the concentration of gully erosion sites on it more than other geologic formations (Fig. 4). The Geology of Nanka and Agulu erosion valleys exhibit large boulders that serve as possible support on which the cuesta-ridges lie. High rate of percolation of the rainfall and differential deposits also facilitate erosion development.

During the rainy season, massive groundwater infiltration into the subsurface geologic units occurs. This high infiltration raises the groundwater levels in aquifers resulting into high pore water pressures and groundwater discharges to the surface and at the sides of river or stream valleys. The groundwater level rises and pushes up pore water pressures beneath the ground surface resulting in effluent seepages, slope stability problems and hence development of gullies and landslides.

4.2. The Role of the Escarpments in Gully Erosion Development

Topographically, the study area consists of elevated and low-lying landscape. The elevated areas form escarpment or cuesta that runs northwest–southeast with low asymmetrical ridge [13]. The escarpment has a crest that stands above 350m above mean sea level. The cuesta is characterized by steep eastward scarp slope and gentle westward dip slope. It forms both surface water groundwater divides thereby facilitating surface water and groundwater flows as well as enhancing gully erosion and landslides development and growth [5]. Most of the gully sites in the area emanate from the slopes of the escarpment and attain maximum depth down slope [13]. Increased mass of water flowing downhill from the crest of the cuesta during the rainy season increases the energy of the moving mass beyond threshold binding energy of the composite soil particles thereby detaching soil particles continuously, transporting and depositing them at the foot of the cuesta resulting in the formation of gully erosion [14]. The area is drained by network of springs streams, rivers and lakes flowing out from both flanks of the escarpment with heavy loads of dislodged/eroded sediments and emptying into River Niger and Anambra River.

4.3. The Agulu-Nanka-Oko-Ekwulobia-Orlu Cuesta and Gully Complex as a Case Example of Potential Urbanization-Failure/Collapse

The Agulu-Nanka cuesta is bordered in the east by the steep scarp slope that trends and ends at the Odo River valley; and towards the west by the gentle dip slope which slopes and terminates into the Idemili River valley. Subtending this cuesta is a regional and huge aquifer from which effluent seepages of groundwater issue out from slope-sides and flow either as springs and into valleys or streams or rivers; they combine with surface water flows to cause gullies and landslides. The major surface water flows include Odo River that flows northwards into the Mamu River which suddenly flows westwards into the Anambra River that discharges into the River Niger; and the Idemili, Orashi and Njaba Rivers that flow westward and also discharge into the River Niger. Both Idemili River and Anambra River as well as their tributaries and distributaries carry heavy loads of clayey/silty/sandy sediments that are transported from uplands of Nanka/Ameki Formations and Imo Shale down into the River Niger and Imo River into the Niger Delta and eventually into the Atlantic Ocean. Along the flow systems of these major rivers are heavy deposits of sands that are commercially-mined and sold for construction purposes; much of the heavy loads of sand deposits being dredged presently in the River Niger come from these denuded cuestas as products of the erosion process. These erosional features in form of rills, channels, gullies and chasmic depressions some of which are of canyon proportions along this cuesta/escarpment occur annually in various grades and dimensions. The population density in the urban and peri-urban towns of Agulu, Nanka, Ekwulobia etc. is very high; deforestation and urbanization programmes are continuously-ongoing at alarming rates; market and agricultural resources have busy schedules; vehicular movements and transportation activities are intensive etc. The infrastructural and development activities

by governments and the people are not properly-planned, -executed or-supervised; and monitoring and maintenance programmes are non-existent.

Despite the above potential environmental instability, governments and people have been carrying out massive development projects in these areas. The lands and environment along the Agulu-Nanka cuesta are geologically and geotectonically quite unstable and should be regarded seriously asuch in planning and executing development projects. Residential houses, commercial centres, road networks and drainages stretch far down into the lowlands/valleys. Buildings are seen perching perilously at the edge of gullies ready to be thrown into the valley at the least moment of adjacent gullies or landslides (Plate 1 and 2). Some of the frontal areal lengths of the aggressive fingers of gullies are advancing into the urban heartlands at the rates of between 2 and 3 m per year while expanding at their widths at about 3 to 5 m wide annually approaching the major roads or have cut them in places.

Fig. 5. *Gully sites and associated socioeconomic lossess.*

4.4. Structural Control of Gully Erosion and Landslides

The tectonically associated structures such are fractures (joints, faults and grabens) also have a stake in the gully erosion formation and development in southeastern, Nigeria. The implications of the neotectonic features and structural effects on gully erosion initiation were outlined [5], [14], [15], [16], [17], [18] and [19]. These neotectonic features originate from the Atlantic Ocean in a NE-SW direction exhibiting zones of potential seismic effects and therefore areas of potential crustal instability within the total environment. These geologic structures form plains of weaknesses or pressure release spots along which future movements, slides, heaves or platform failures may occur whenever some energy/pressure event triggers off such an action. Such pressure actions may be from natural causes or anthropogenic effects in the immediate environment. The deforestation and urbanization impacts, the hanging hills, slopes, lowlands and valleys found all over the erosion prone-areas are evidence of these plains of weaknesses that can trigger off gullies and landslides within the study area.

5. Conclusion and Recommendations

The government at all levels and the people must consider the impacts and implications of their developmental activities on these cuestas. The prevalent anthropogenic activities may precipitate tragic disasters where many communities may lose more of their lands and infrastructure to wide scale gullies and landslides thereby posing potential debilitating damages to the socioeconomic growth of the area.

Drastic control measures should be taken to checkmate the problems of gully erosion and landslides that annually-ravage the environment, destroying socioeconomic resources. The immediate measures to be taken may include all or a combination of the following:

(a) Proper control measures involving Total Water Catchment Management Strategy (TWCMGS) should be employed. Environmental and Engineering Sciences professionals with proper and good civil engineering plans/designs ought to be used in executing projects in checking floods, soil and gully erosion and landslides in the Southeastern States of Anambra and Imo.

(b) Below the extensive stretch of the escarpment is a regional huge aquifer deposit of good groundwater quantity and quality. The surface waters in nearby lakes, streams and rivers are polluted/contaminated by inflows from erosion and floods. It is equally unfortunate that people of the towns and communities of these areas lack potable water supplies for domestic purposes. It is suggested that a network of giant boreholes should be located at strategic points to tap the aquifer for community uses; and this will lower the pressure heads and reduce groundwater discharge into gully faces.

(c) Funded research for the locations of unstable cuestas/escarpments in the towns and communities is also recommended and replan/redesign the way and manner infrastructural development projects are executed to prevent possible failures of such structures. The already existing infrastructure and landscape should be properly-monitored and managed to prevent possible collapse or failures in the

environment.

(d) The States must discourage bad agricultural and civil engineering practices that are erosion-causative in badlands such as deforestation, unplanned agricultural practices, urbanization, bad roads and drainage network-constructions, blocking of drainages with solid wastes and building on wetlands.

(e) Laws against environmental destruction should be enacted and strictly-enforced by government.

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